Dynamics of Semi-Enclosed and Coastal Seas: Numerical Models and Altimetry

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LONG-TERM GOAL

Our long-term goal is to establish and utilize comprehensive, data-assimilative numerical models of the oceanic state in semi-enclosed, marginal, and coastal seas of naval interest, in order to obtain a better understanding of the prevailing processes, and to assist in the establishment of a reliable nowcast/ forecast capability in these regions. Of particular interest is an increased understanding of the interaction of marine ecosystem and the physical environment, in so far as it affects the primary productivity and optical properties of the upper ocean.

OBJECTIVES

Our primary objective is the development of comprehensive models of the state of the ocean assimilating altimetric, IR (MCSST) and other remotely-sensed (and when feasible in-situ) data. Such data-assimilative models can then be used to study the prevailing processes (through accurate hindcasts) and also to establish predictive (nowcast/forecast) capability of potential use to naval operations. For realistic depiction of the optical properties of the upper ocean, one also needs a coupled physical-biological ecosystem model of the upper ocean, and this is the current focus of our efforts.

APPROACH

Not unlike the practice in atmospheric research, a better understanding of the circulation, the air-sea exchange, and the prevailing dynamical, physical and biological processes, is best obtained from a suitable combination of dynamics and data. So we rely on data-assimilative models, relying primarily on altimetric and AVHRR data. Since dynamical factors often overwhelm others in issues related to primary biological productivity and air-sea exchange, it is prudent to get the underlying circulation and its variability right, before attempting to model aspects such as the onset and demise of the spring and fall blooms in regional seas. One promising approach is a data-assimilative dynamical model coupled to a primary productivity model. This is the approach we are taking for the JES (Japan/ East Sea) studies.

As a necessary first step, we are developing a coupled physical-biological ocean mixed layer model suitable for ecological studies in a wide range of ocean environments. This model is general enough to test a wide range of ecosystem parameterizations. Also, the flexibility of this model will enable us to determine the minimum ecological model complexity necessary to accurately reproduce observed biological state of the upper ocean. The resulting model will be suitable for inclusion in regional or global ocean models of weekly to interannual time scale. At present, we are working on a one-dimensional version of this General Ecosystem Model (GEM) and are validating this against available biological data sets. Versions suitable for three-dimensional modeling are forthcoming and the next step is incorporation into a nowcast/forecast model of the Sea of Japan.

WORK COMPLETED

The 1D version of GEM is in place, and results compare favorably with existing ecosystem models of BATS data and data sets obtained at OWS PAPA. We are in the process of determining the minimum complexity of the coupled model necessary to reasonably reproduce these data. Our graduate student Scott Stewart is assisting with the development of the GEM model. The most general formulation allows for 10 components: nitrate, ammonium, bacteria, dissolved nitrogen, and two categories each of phytoplankton, zooplankton, and detritus. In addition, a trace component is modeled for application to High Nitrogen Low Chlorophyll (HNLC) regions of the world. The formulation with minimum complexity is the NPZ model subcase, with only nitrate, phytoplankton and zooplankton components. A sketch of the general ten component model is shown in Figure 1.

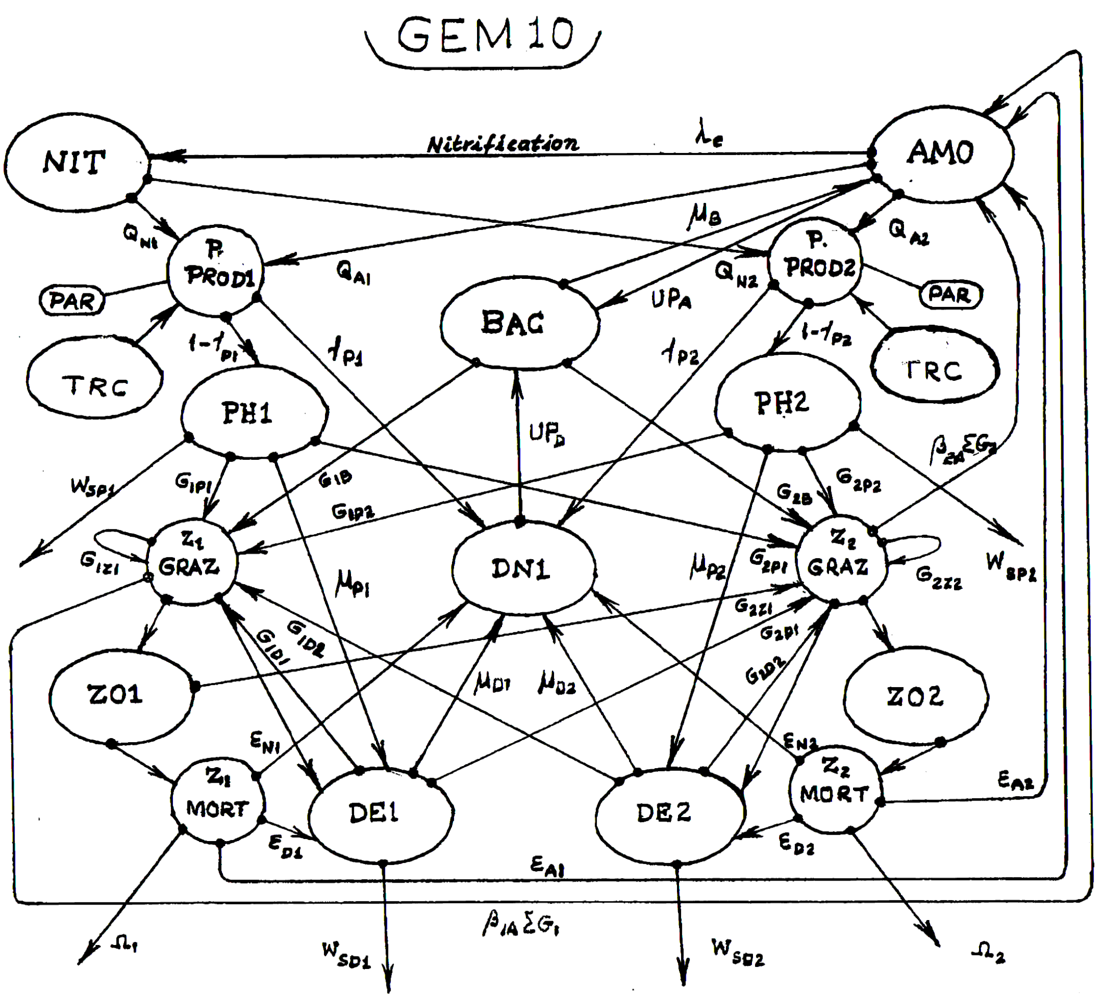

Figure 1: Ten Component General Ecological Model (GEM-10)

We have assisted and supervised a NASA Fellowship doctoral student Craig Tierney in establishing a near-global tidal model with unprecedented accuracy in shallow water regions of the world (Tierney et al. 1999).

The summer of 1998 produced anomalously high and prolonged flooding in Bangladesh with 60% of the country being under water for nearly 2 months. Dr. Joseph Lopez and I used a data-assimilative model of the North Indian Ocean to hindcast this event, which showed that anomalously high sea level at the mouth of Bay of Bengal was responsible for the prolonged flooding (Webster et al. 1999). We also made a hindcast for 1993-1999 and have developed a nowcast/forecast capability. The model used has high vertical resolution (38 vertical levels) and $1/2^o$ horizontal resolution, and good mixed layer physics, and well-suited to hindcasts and real-time nowcasts of the state of the NIO.

An ocean-atmosphere coupled model of the Gulf of Mexico was used to simulate hurricane Opal. The model couples our ocean model to the NCAR MM5 regional model of the atmosphere. We have shown that the presence of eddy Aggie stradling its path resulted in some intensification of Opal, but not as much as is attributed to it in literature (Bao et al. 1999).

RESULTS

Our ecosystem modeling effort reveals that similar results can be obtained from ecological models of varying complexity. However, some skill is necessary to properly tune the parameters for each model configuration. An example simulation is the application of the 5-component submodel to simulate BATS data from 1990 to 1994. Figure 2 shows the changes in nitrate, ammonium, phytoplankton, zooplankton and detritus during 1990-94 for one particular choice of biological parameters. The results show strong springtime phytoplankton blooms. The bloom for 1994 is not as well pronounced as in earlier years because of weak wintertime mixing as indicated by a shallower wintertime mixed layer.

The NIO results can be seen on the North Indian Ocean real time nowcast website - http://www-ccar.colorado.edu/~kantha/nio/nio.html . The model does a good job of depicting the three-dimensional state of the NIO during 1993-1999 and has indicated a plausible cause of prolonged and severe flooding in Bangladesh during the summer of 1998.

Regional coupled ocean-atmosphere models are ideally suited to simulation of extreme events in a region. Application of such a model to hurricane Opal in 1995 has improved our understanding of the causes of its rapid intensification from category 2 to 4 in a short span of time. The role of a warm core eddy in its path has been clarified.

IMPACT/APPLICATIONS

The GEM model enables easy reproduction of earlier ecosystem models in literature as well as simulation of available data sets from OWS PAPA and BATS time series. Because the model includes a highly skilled physical model, many investigations of the role of microscopic marine life are possible, including the study of carbon sequestering by phytoplankton, the rate of primary and secondary production and the expected data observed by satellite-borne ocean color sensors such as SEAWIFS. A better understanding of the primary productivity and hence the optical properties of the Sea of Japan waters is important to naval operations in the region, especially around the subpolar front.

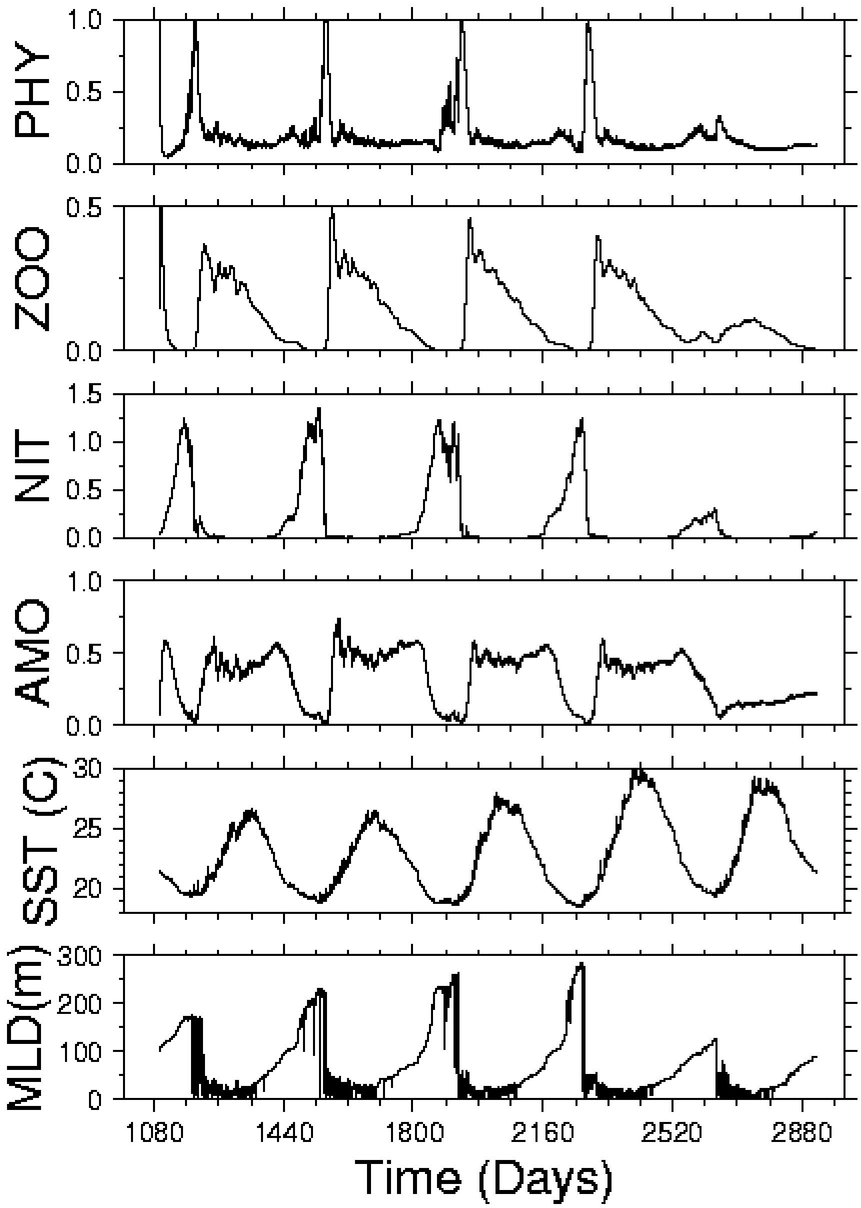

Figure 2: GEM results at BATS site. Units of biological components are mM/m^3

A global tide model accurate in both shallow and deep regions of the global oceans is of importance to naval applications in the littoral, and extension of precision altimetery into shallow waters.

The North Indian Ocean is not only of strategic importance to the US Navy, but its summertime monsoons are crucial to the welfare of nearly half the world population. A better understanding of the oceanic state during the southwest monsoons is therefore quite important.

TRANSITIONS

None at this time.

RELATED PROJECTS

Our research on the Sea of Japan is coordinated with the ONR Japan (East) Sea DRI. We have also been working on coupling the NIO dynamical model to a biological primary productivity model under a related DoD AASERT program.

PUBLICATIONS

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